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SPRAY-DISTRIBUTION PATTERNS FROM LOW LEVEL APPLICATIONS WITH A HIGH-WING MONOPLANE [1]

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INTRODUCTION

The early research investigations pertaining to aerial applications of sprays at low flight levels showed that the rate of deposit and the uniformity of the deposit rate varied both across the application swath and along the line of flight. The magnitude of these variations differed with the type of aircraft used and with the height of the application. Pattern variations were also noted between applications made from a high-wing monoplane and those from a Stearman[4] or an N3N biplane. However, no attempt was made in the early investigations to correlate spray-pattern variations with the position of the boom or with its location in respect to that of the wing.

The early studies of Chamberlin and others[5] showed that the vortical forces generated in flight by the propeller and at the wing tips largely governed the swath width and uniformity of deposit for any given flight elevation with any given nozzle arrangement.

EQUIPMENT USED

In 1961 two series of tests were conducted using a government-owned Cessna 182 high-wing monoplane to determine how placement of the boom affected the shape of the spray-deposit pattern and the width of swath covered by the pattern. The Cessna airplane was equipped with a modified Sorensen external spray tank and pump assembly. In this installation the spray tank was mounted underneath the fuselage below the cockpit. A short 32-inch section of boom was fastened to the front of the spray tank to supply spray liquid to the outboard boom sections. This short center section of the boom remained in a fixed position during all of the tests.

In one series of tests, curved booms were used. The two outboard sections of the booms extended from each end of the 32-inch center section, upwards at an angle along the back of the wing strut to a point 6 inches below the wing, and then outboard and parallel to the wing for a maximum distance of 6 1/2 feet (figs. 1 and 2).

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[2] Respectively, agricultural engineer and aircraft pilot, Agricultural Engineering Research Division, Agricultural Research Service.

[3] Entomologists, Entomology Research Division, Agricultural Research Service.

[4] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

[5] Chamberlin, J. C., Getzendaner, C. W., Hessig, H. H., and Young, V. D. Studies of airplane spray-deposit patterns at low flight levels. U.S. Depart. Agr. Tech. Bul. 1110, 45 pp. 1955.

Figure 1.--Curved boom mounted to strut and wing of a high-wing monoplane.

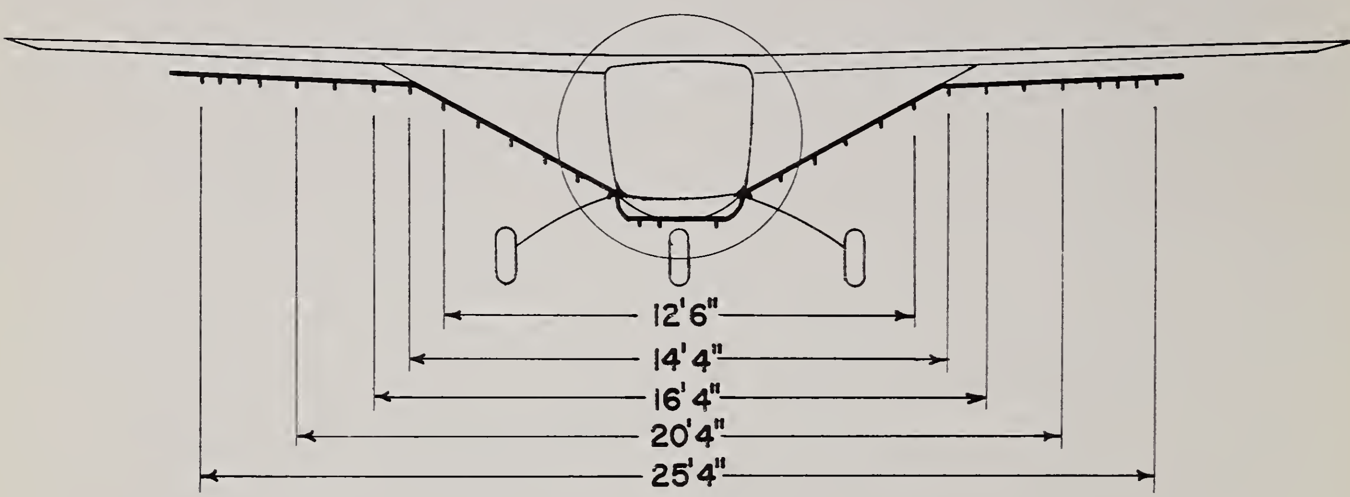

Figure 2.--Various boom lengths experimented with in tests with the curved boom.

In the second series of tests, straight booms were used. The outboard sections were attached to the center boom by use of hose couplings and extended toward the wingtips at an oblique angle. Each outboard boom was 15 feet long and was mounted in four different positions so that tests could be made with the outer ends anchored at 12, 24, 40, and 66 inches below the wing (fig. 3).

Each test in the series comprised one boom position, and the tests of boom position consisted of three or more duplicate applications. The speed of application was approximately 110 m.p.h., the height ranged from 4 to 6 feet, and pressure in the boom was approximately 25 p.s.i. Whirljet nozzles size B10-8 were used in the center boom section; teejet nozzles with disk-type orifice size 8 and core size 46 were used on the outboard booms.

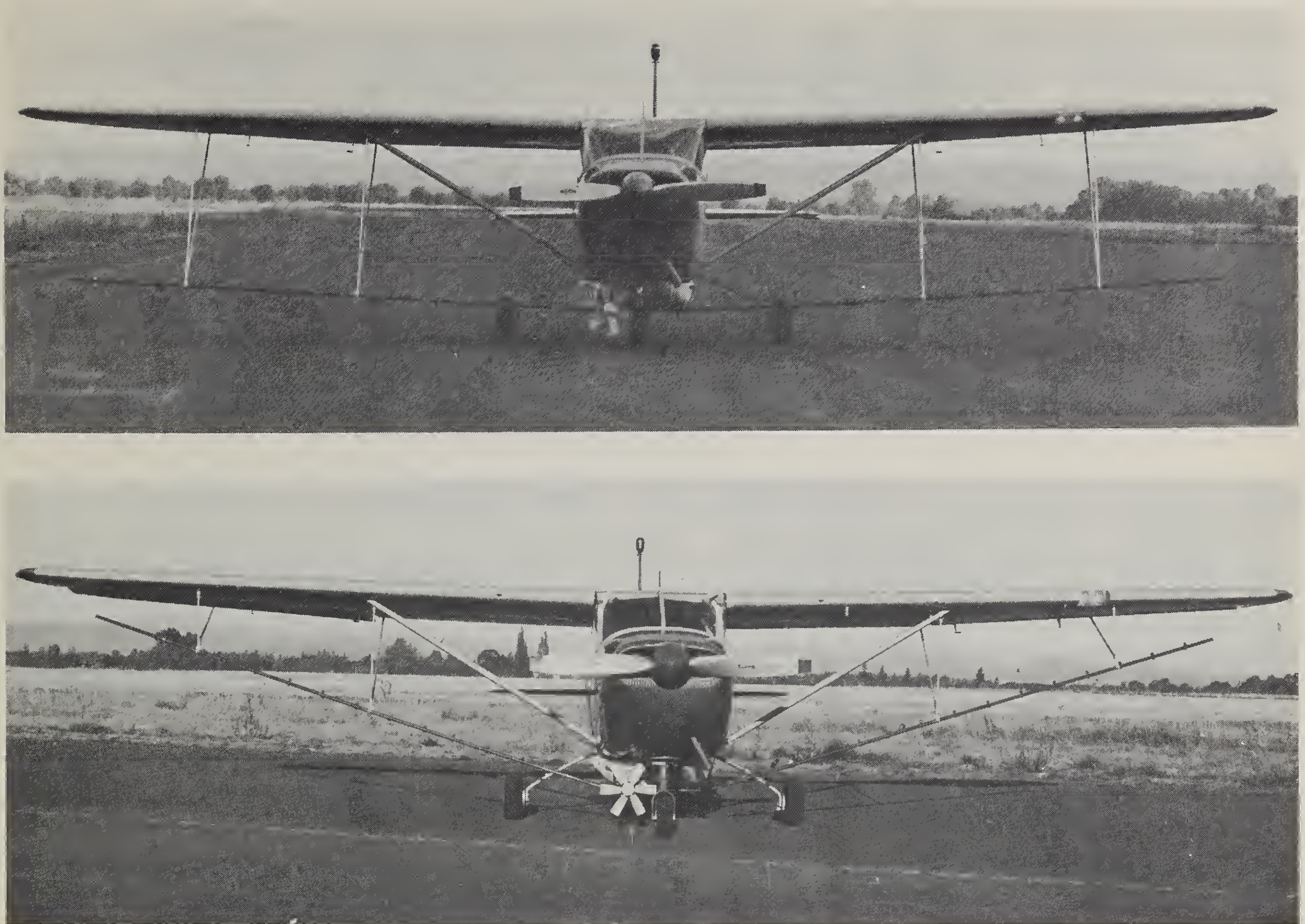

Figure 3.--Straight boom mounted on a high-wing monoplane at an oblique angle. Upper photo shows outboard boom ends anchored 66 inches below wing; lower photo, boom ends anchored 12 inches below wing.

SAMPLING PROCEDURE AND RATE DETERMINATION

The amount of spray that was deposited across the treated swath was computed by the dye-recovery method. The spray was water to which enough water-soluble dye had been added to produce optimum readings on the colorimetric scale. Numbered stainless steel collection plates of known size were spaced at 1-foot intervals along lines to collect the spray deposited in the flight line. These transect lines were 100 feet long and were positioned at right angles to the line of flight and across the swath being treated. Records were kept of the number and position of all plates in each transect line. After each application of spray, the collection plates were gathered and stored in light-proof boxes. Plates were then taken to the laboratory where the dye-laden spray deposited on each plate was recovered by washing the deposit from the plate with a known volume of solvent.

The amount of dye deposited-and hence the rate of deposit-was determined by making a colorimetric reading of the solvent used in washing the spray from the plates. The numerical reading of the color intensity multiplied by a conversion factor determined the rate of deposit at a sampling position. The conversion factor was obtained by substituting the numerical colorimeter reading of a known dilution of the spray mix into an algebraic formula and computing the equation. The formula used in these calculations and in USDA Technical Bulletin No. 1110

is: $R = K \frac{C}{B}$. The use of this formula is also demonstrated in the work of Deonier and others.[6] The formula is derived on the basis of a known dilution of spray mix and a known quantity of solvent used to recover the deposited spray from the sampling area.

Two and sometimes three transect lines of collection plates were used during each spray application to collect samples of the deposited spray. Each test in a series of tests for a given boom position consisted of three or more duplicated applications. The deposit rate for any given boom position represents the average of eight or more sampling stations parallel to the line of flight. The average rates were plotted for boom position and rate and connected by a line to produce the deposit curves shown. The mean rate of deposit across the treated swath is shown by a dotted line. The values for the mean rate were obtained by dividing the sum of the deposit rates for the total treated swath by the total number of stations (collection plates) on which spray was deposited.

CURVED BOOM TEST SERIES

The first series of tests used the curved boom, which extended from the center section up the back side of the wing strut and then outboard under the wings (figs. 1 and 2). The objective of these tests was to determine how the length of boom affected the width of swath and the uniformity of deposit in the swath. The effective boom was extended to varying lengths by adding or removing nozzles from the segment of the boom that extended outboard from the wing-strut bracket. Five overall lengths of boom were tested-12'6", 14'4", 16'4", 20'4", and 25'4" (fig. 2). Visual observations during the spray applications were made to ascertain if nozzle distance from the wingtip influenced the pickup of released spray by air rotating in the wingtip vortices.

The curves of deposit rates for this series of tests show that the swath width ranged from 28 to 30 feet when measured at the mean deposit rate for the 12'6", 14'4", and 16'4" boom lengths (fig. 4A, B, and C). The average deposit-rate curves show that approximately 85 percent of the recovered spray was deposited in the swath that lay directly under the 36-foot aircraft span, and only 15 percent was deposited in the treated-swath zone located outboard from the tips of the wings (fig. 4A, B, and C).

Extending the boom to 20'4" (10'2" each side of center) increased the swath width to 48 feet when measured at the mean deposit rate. At this boom length, 34 percent of the deposited spray was picked up and conveyed outboard from the boundaries of the swath described by the wingtips (fig. 4D). Lengthening the boom to 25'4" increased the total amount of spray conveyed and deposited beyond the wingtips from 34 to 47 percent and increased the swath width to 69 feet if measured from the outboard peak to the right of center (fig. 4E).

If the two high-deposit zones in the center section of the curve for the 25'4" boom are momentarily disregarded because they are not directly influenced by the wingtip vortices, the reader will notice two other high-deposit areas approximately 28 feet left and 36 feet right of center, which were the result of airflow patterns at the wingtips. The discharge released by the outboard nozzles was picked up and conveyed outboard 14 to 16 feet by air flowing into the vortices and then was deposited. The total amount of spray deposited outboard of the wingspan was nearly one-half the total spray deposited in the single-swath application.

The data from this series of tests show that when the curved design of boom mounting is used, the outboard boom nozzles should be placed at least 10 feet from center to obtain an

[6] Deonier, C. E., Getzendaner, C. W., Young, V. D., and Winterfeld, R. G. Mylar plastic tags for sampling spray deposition on individual leaves and surfaces. Econ. Ent. Jour. 56 (1): 114-115. 1963.

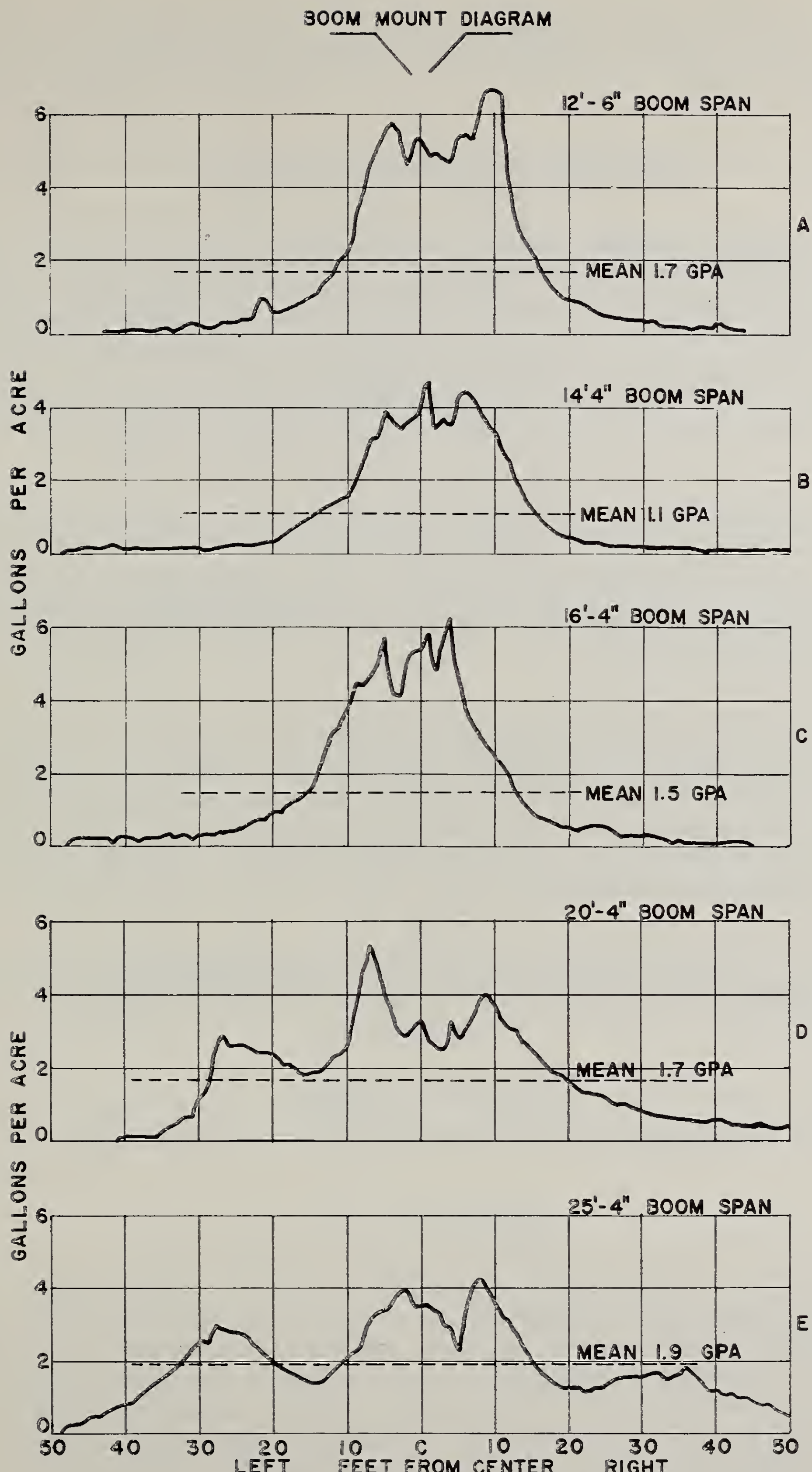

Figure 4.--Spray-deposit patterns with booms of various lengths mounted to strut and wing of high-wing monoplane: A, boom 12'6"; B, 14'4"; C, 16'4"; D, 20'4"; E, 25'4".

effective swath[7] of 50 feet or more. Secondary zones of peak deposit occur as a result of the airflow into the wingtip vortices. Droplets of spray in the expanding wingtip vortices remain suspended until the dissipating air currents can no longer support the droplets, and then gravity causes them to settle.

OBLIQUE BOOM TEST SERIES

In this series of tests, a straight boom was attached to the short center boom by use of a flexible connection and the spray pattern studied when the boom ends were fixed at four separate distances below the wing. In an approximately horizontal position, the outboard boom ends were about 66 inches below the wing (fig. 3). In the next test, the boom ends were raised to 40 inches below the wing, then to 24 inches, and finally to 12 inches below the wing (fig. 3). Duplicate spray applications were made of all these boom positions, and the average rate at each position was computed and plotted for separate boom-position runs (fig. 5).

The average deposit curve for the 66-inch boom position shows a high deposit zone in the center segment of the swath and secondary peaks about 21 feet on both sides of center (fig. 5A). For the remaining tests in this boom test series, one nozzle 12 inches left of center and one 6 inches right of center were removed to overcome or decrease the amount of peaking in the center zone of the swath. The swath width for the 66-inch boom position was approximately 53 feet measured at the mean rate level.

It should be noted that the plotted curve for the 40-inch boom position is triangular in shape (fig. 5B). The peak rates in the outboard zones and center segment have decreased. The curve pattern is broad and has a swath width of about 55 feet if measured at the mean rate level. When using multiple swaths with overlapping, the application swath could be increased to about 71 feet and still maintain a rate deposit level that is equal to or greater than the mean rate level for the single swath application.

Curves for the 24- and 12-inch boom positions (fig. 5C and D) show that as the end of the boom was brought closer to the wing the amount of outboard peaking increased and that these peaks were most pronounced for the 12-inch boom position.

The data for this series of tests show that the widest effective swath with the least outboard peaking was obtained when the boom end was mounted 40 inches below the wing.

SUMMARY

The study shows that in order to obtain the maximum swath width with the least amount of outboard peaking, the spray must be introduced into the expanding wingtip vortex at a point where the individual drops will be merely deflected outboard and then assume a downward trajectory. As has been mentioned previously the outboard flow of air into the expanding wingtip vortices transplants the droplets and is very essential to obtain a deposit swath which is wider than the nozzle span. Spray pickled up and conveyed outboard by the airstream should not be introduced into the vortices where the airstream is intense enough to lift the spray and fold it back inboard before gravity causes the droplets to settle.

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[7] "Effective Swath" means the maximum width of swath over which a deposit equal to the mean rate is obtained, taking into account overlaps of adjacent swaths.

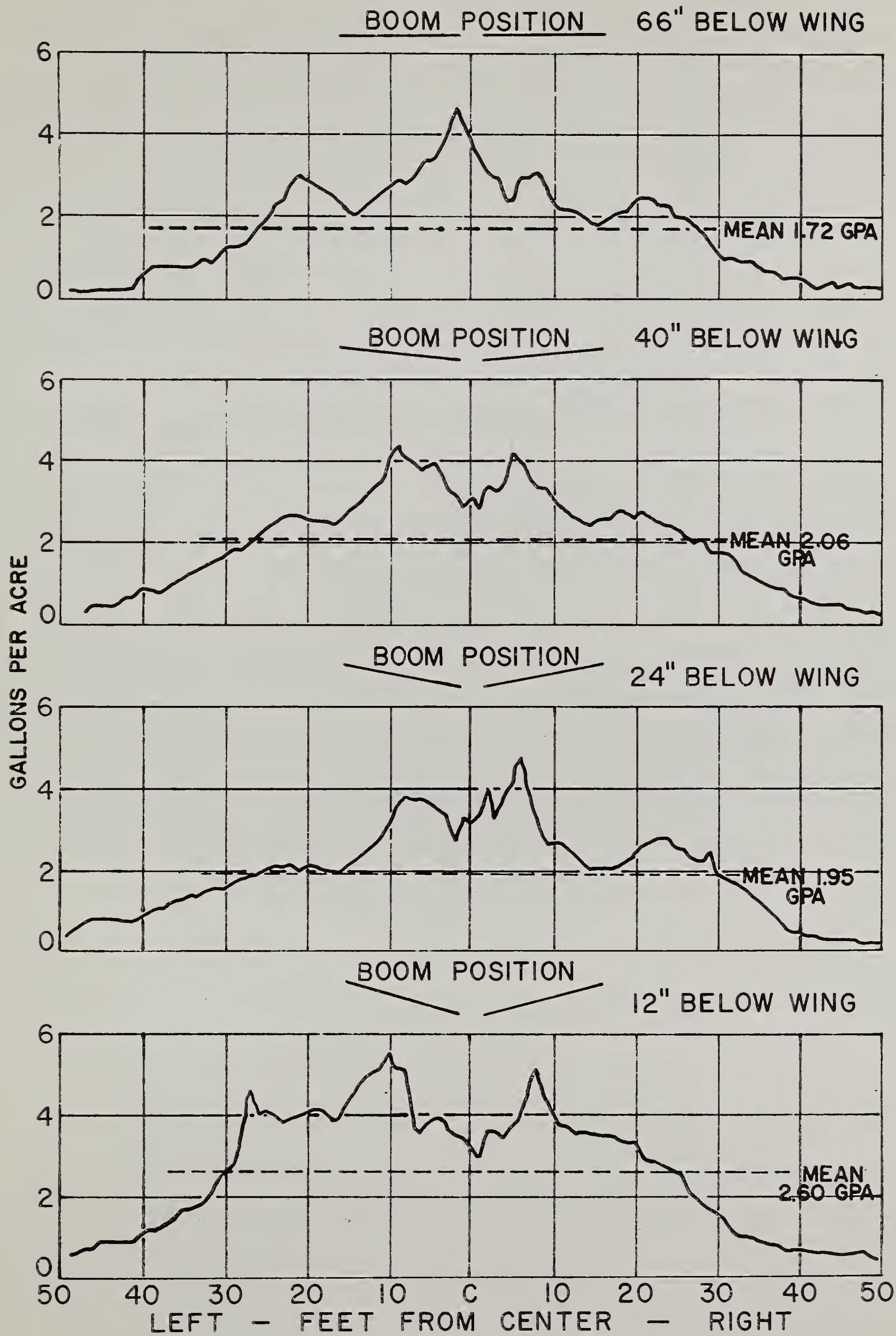

Figure 5.--Spray deposit patterns for various positions of oblique boom mounted on a high-wing monoplane: A, 66" below wing; B, 40" below wing; C, 24" below wing; D, 12" below wing.

A comparison of plotted curves for the two series of tests indicates that the widest effective swath and the more desirable shape of pattern were obtained by use of the straight tubular boom mounted obliquely and when the outboard ends of this boom were 40 inches below the wing. The data indicate that a straight boom mounted at an oblique angle in which the outboard nozzle of the boom sections is positioned 40 inches below the wing will produce the widest and most desirable shaped pattern for this type of aircraft (fig. 6).

Figure 6.--Spray curtain when ends of oblique boom are 40 inches below wing.

USE PESTICIDES SAFELY

If you use pesticides, apply them only when needed and handle them with care. Follow the directions and heed all precautions on the container label. If pesticides are handled or applied improperly, or if unused portions are disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, honey bees and other pollinating insects, fish, and wildlife, and may contaminate water supplies.